January 22, 2019

PHYS-E0483 Advances in New Energy Technologies
Spring 2019: Project Work

General

As an alternative to a conventional written exam, we offer a Project-Based learning experience. You may consider the following option to replace the exam in spring 2019:

1) You get 10 out of max 12 home exercise points (if you haven't succeeded to get the necessary amount, you may ask for additional questions from the course assistants)

2) You carry out a so-called Project Work (PW) in a team of typically 3 persons on a given topic, or alternatively, on an own topic (which need to be within the scope of the course and accepted in before-hand)

The aim of the Project Work is to apply the knowledge gained through the course into topical problems of practical relevance. The aim is to perform a creative task by exchanging, communicating, and integrating ideas to solve a challenging problem. The success of the PW will depend on the activity of each member of the team, meaning that active participation is necessary (e.g. if one team member does not work adequately, this should be reported to the assistants).

A PW includes important phases such as collective understanding of the problem and task, organizing the work among the members, research of relevant literature and data, analysis work, synthesis of the results, writing the report, and delivery, among others. The report is 15-25 pages long, it should also include quantitative results and demonstrate your elaboration of the problem given. The reports should be written in a scientific style, e.g. include a clear structure: a cover page with PW title, names and student numbers, numbered chapters (Introduction, Method, Results, Discussion, Conclusions, References) clear figures and tables, formatted reference list, etc. You may write the report in Finnish, Swedish, German, or English. The report will be graded 0 (reject) to 5 (excellent) and we expect you to deliver it by May 27th at latest through MyCourses. If you, however, need your scores earlier deliver the report by April the 16th, 2019. A pitching session will be held to present the status of the PWs at the end of the course.

Teams will be formed early February 2019 (course assistants will coordinate this and send a notice on how teams are formed). The topic outlines are available here (chose only one). Tutoring sessions, if necessary, will be arranged in the first weeks of March 2019. Some additional material e.g. data files will be linked to MyCourses. Some data (e.g. demand, solar and PV profiles) and tools have already been issued during the exercises and lectures

Topics 2019

The Project Work is done on **one** of the following 4 subjects. All themes are timely and relevant for advances in new energy technologies. Your Team is free to choose any one of these:

1) From coal to clean energy in Helsinki

Helsinki City's long-term vision is that energy production should to be carbon free by 2030. A major challenge for the city is that most of the heat produced comes from combined heat and power plants, using coal or gas. Also, fossil-fuel peak boilers are in use. In particular the coal-CHP plants have high CO2 emissions, though they also have a high fuel-to-energy efficiency. Slightly less than half of all heat and less than a quarter of the electricity is produced by coal-CHP.

Your task is to replace the coal-CHP plants in Helsinki with clean energy schemes. You can use different energy sources and flexibility measures.

Your report should include:
i) A summary on how Helsinki produces its electricity and heat presently, ii) elaboration of the energy system challenges which arise if closing the coal-CHP, iii) justification and description of your choices and an energy analysis of these to show that they satisfy the demands (also description of the methodology used), iv) effects on costs and emissions, v) your master plan (technology mix, technical characteristics) and a reflection on cons and pros of your plan.

Hourly data on Helsinki (heat, power, solar, wind) is found in MyCourses. Helsinki Energy HELEN has summary data on their present energy production mix.

You may also pick any other major city in Finland and abroad (e.g. your home town) instead of Helsinki if you find it a better case for your Team.

(this has also been the topic in course C6370 Fundamentals of New Energy Sources; if you've already done a PW on this, chose another topic)

2) 100% renewable power system

Future energy systems may increasingly be based on distributed power such as photovoltaics (PV) along decreasing prices. At the same time, different storage technologies such as batteries or power-to-gas systems become more effective and cheaper. Scientific literature on so-called 100% renewable energy systems are increasing, some cities and even a few countries have announced plans in this direction by 2050.

This year we will pick solar PV, wind power, and storage for more detailed analysis. **Your task is to plan an optimal national power system which works 100% on solar energy and wind power** in 2050. The specific questions that you need to analyze are the following:

a) Justify the technical solutions for solar PV, wind power, and storage solutions in your case for year 2050. Also, include an estimate of the unit costs of the technologies.
b) Using hourly data for power demand, wind power, and solar PV (unit profiles), size the required wind power (GW), solar PV total size (GW) and storage (GWh) to supply all power demand needed. You need to do some simulations and optimization (e.g. Excel Solver) to find the optimal solution. Also, including unit costs in your calculation may help to find the optimum more easily.
c) Compare your results in b) to a case with 100% PV (0% wind) and 100% wind (0% PV)

d) Make an economic analysis of your results in b) and c): estimate the total investment needed and the LCOE of your solution.
e) Discuss the feasibility of above plans including pros and cons.

3) Power-pack design

Through rapid battery development, distributed power generation in small scale e.g. for households could be a mainstream power option in the future. For example, a PV-battery system in Finland could already now produce 70% of the yearly electricity demand of a household. A key future question will be how to produce the remaining 30% in the most effective way, which may correspond to around 1 MWh electricity per year for a household.

Your task is to sketch and design a fuel-based small power pack, which is able to produce the 1000 kWh of electricity for 3-4 months of the year for a household-sized load with minimum costs and emissions. The exhaust heat, if produced, could be used for heating. The system complements e.g. a PV- or wind-battery system.

In analyzing this question, you should address the following aspects as well:
a) Sketch the technical principle and choices, system layout and technical characteristics of the power-pack unit
b) Make a techno-economic analysis of its performance/energy balance, emissions, costs
c) Think about user acceptance of your power-pack !
d) Present a business model for your case /OR/ Demonstrate the unit in real size in lab e.g. out of cardboard

The technical choices are not restricted.

4) Matching analysis of solar and wind ramp ups/downs with smart power engines

Your task is to analyze the feasibility of smart-engines for compensating the variations in variable renewable power. Photovoltaics (PV) and wind power are the fasting growing power sources worldwide. Their innovation potential is large and costs are expected to drop. In some scenarios wind and PV could produce over half of the global electricity demand in 2050. PV and wind are variable renewable energy sources. If used in large-scale some back-up, e.g. storage or reserve power, is necessary to compensate for mismatches between supply and demand.

Gas-engines employing natural gas or bio-gas have a very fast response time for which reason these could be a potential technology to be used in connection with large solar and wind power schemes. Gas-engines are delivered e.g. by the Finnish Wärtsilä Ltd.

Your tasks are the following:
a) Analyze what kind of ramp conditions could solar and wind cause (MW/h, MW/s) on different scales typical for primary, secondary and tertiary reserves
b) Investigate the ramping properties of smart engines (MW/h, MW/s)
c) Prepare a "matching" analysis of smart-engines and Solar/Wind schemes and analyze how well engines could undertake such tasks, e.g. in a hypothetical case for Helsinki city (or a city of your choice), sketch the engine concept to match with a RE power that produces >70% of city's power in a year. You could also think here about an engine-CHP system with P2X (e.g. P2H) strategies.